UNITED STATES DEPARTMENT OF AGRICULTURE
Rural Electrification Administration
Operations Division

SUBJECT MATTER FOR
GRAIN AND HAY DRYING
TRAINING SCHOOL
FOR
ELECTRIFICATION ADVISERS

July 1952

827790

A. INTRODUCTION

I. U. S. Production of Animal Feeds, etc., in 1950

A. 100,000 Tons of Hay

1. Alfalfa	35,254,059 Tons	
2. Clover	23,956,678 Tons	
3. Lespedeza	7,933,598 Tons	
4. Peanut Hay	673,881 Tons	
5. Soy Bean Hay	1,380,134 Tons	

B. 100,000,000 Tons of Small Grain and Seeds

1. Wheat	30,213,597 Tons	- 1,007,119,930 Bushels
2. Oats	18,166,275 Tons	- 1,135,392,209 Bushels
3. Sorghum Grains	3,768,844 Tons	- 141,744,437 Bushels
4. Barley	6,171,898 Tons	- 220,424,918 Bushels
5. Rye	463,764 Tons	- 16,563,013 Bushels
6. Rice	2,504,095 Tons	- 89,431,985 Bushels
7. Flax Seed	835,293 Tons	- 40,189,048 Bushels

C. 100,000 Tons Corn - 2,778,432,462 Bushels

II. Kansas Production

A. 2,285,216 Tons of Legume Hay

1. Alfalfa Hay	2,000,000 Tons	
2. Clover Hay	127,482 Tons	
3. Lespedeza Hay	150,090 Tons	
4. Other Legume Hay	7,664 Tons	- Soy Bean Hay
5. Prairie Hay		

B. Tons Small Grain

1. Wheat	4,367,273 Tons	- 145,000,000 Bushels*
2. Oats	243,638 Tons	- 15,000,000 Bushels
3. Sorghum Grains	584,653 Tons	- 29,000,000 Bushels
4. Barley	103,260 Tons	- 3,500,000 Bushels

C. 2,224,270 Tons Corn or 62,000,000 Bushels

*About half of maximum production

III. Production and Storage

A. Planting and Harvesting

1. Highly Mechanized
    a. Combines - In Kansas - 61,365
    b. Corn Pickers - In Kansas - 11,954
    c. Pick-up Balers - In Kansas - 8,053
2. Reduce Labor
3. Have Increased Losses in Field and Storage

B. Grain Handling Problems

1. Machines Highly Efficient
    a. Harvest Grain Before Ready to Store
    b. Results - Corn up to 30% Moisture
       Small Grain to 20% or More
        (1) Machines Stand Idle Mornings and Late Afternoons
        (2) Causes Field Losses
            (a) Shattering and Lodging
            (b) Storm Damage
        (3) Retards Fall Plantings
        (4) Causes Excessive Weather Losses

2. Marketing and Storage Losses
   a. Market Price Cuts
      (1) Due to Glutted Market
      (2) Due to High Moisture
      (3) U. S. Pure Food Laws
   b. Storage Losses
      (1) Losses Occur When Moisture Content Above
         (a) Ear Corn 18%
         (b) Shelled Corn 13%
         (c) Small Grains 12% - 14%
         (d) Sorghum Grain 14%
      (2) Heat and Mold
      (3) Insect Infestation
      (4) Migration of Moisture
         (a) Due to Heat In Grain
         (b) Causes Natural Air Circulation in Grain Mass
         (c) Results in Condensation of Moisture in Top Levels of Stored Grain
            (1.1) Due to Cooling of Warm Air
            (1.2) Causes Spoiling of Top Layer

IV. Storage Methods and Handling Need Improvement
   A. Four and one-half Million Tons of Grain Spoils
   B. Rats and Mice Take Great Toll
   C. Oxidation Causes Heavy Losses
   D. Weevils Very Destructive

V. Estimated Losses of Legume Hay Feed Value
   A. Twenty-Five Percent of Feed Nutrients
      1. Leaf Shattering Caused by
         a. Leaves too Dry
         b. Turning, to Dry Wet Hay
      2. Leaching and Bleaching
      3. Effect Loss of Vitamin A
         a. Frequently 100% Loss
         b. Needed for Milk Production
         c. Needed for Animal Health, Growth, and Reproduction

   B. Lowers Consumption by Animals
      1. Take #3 Hay as Base
         a. Animals Consume Limited Amount
         b. Will Eat 10% more #2 than #3
         c. Will Eat 10% More #1 than #2
      2. Requires Supplemental Feeding of Grain and Protein Concentrates
         a. To Maintain Milk Production
         b. To Maintain Health and Growth
         c. First Quality Hay Can Save 25% or More of Supplementary Feeding

VI. Estimated Maximum KWH Kansas Could Use in Crop Processing

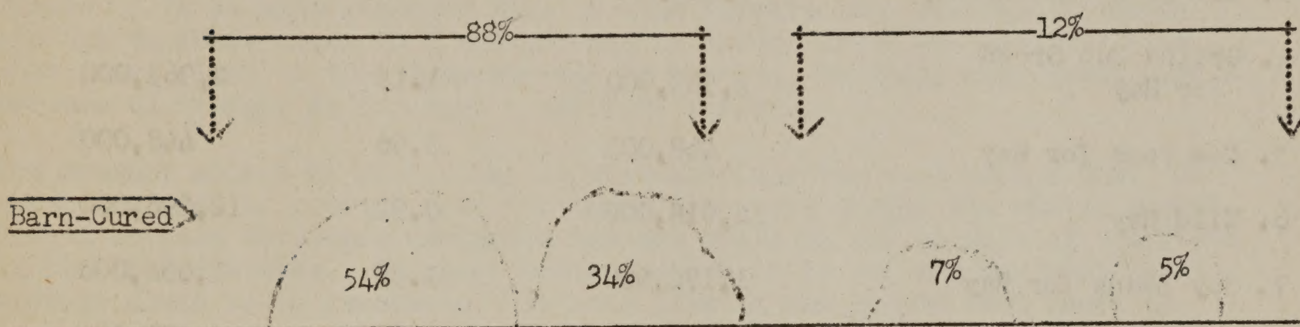
A. For Hay Drying	@ 50 kwh per Cured Ton	114,260,000	KWH
B. For Corn	@ $1\frac{1}{2}$ kwh per Bushel	30,000,000	KWH
C. For Small Grain	@ 1 kwh per Bushel	300,000,000	KWH
		444,260,000	KWH Annually

VII. TVA Records of Hay Quality

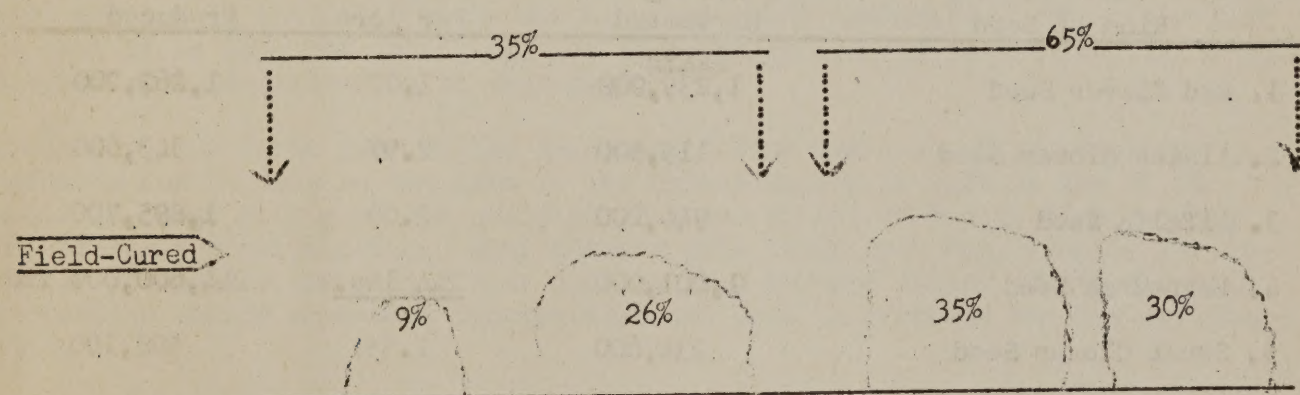
TVA CHART

April, 1945

Effect of Hay Drier on Hay Quality



Grade Requirements for Alfalfa	U. S. No. 1	U. S. No. 2	U. S. No. 3	U. S. Sample
Percent Leaves	40% or More	25% or More	Less than 25%	Hay which contains more than 15% foreign material, or which is otherwise of distinctly low quality.
Percent Green Color	60% or More	35% or More	Less than 35%	
Maximum Percent Foreign Material	5%	10%	15%	



Average of 91 Samples Collected by TVA - 1942, '43, '44, from Farms in Tennessee and Virginia. Grading Done by USDA.

TABLE I

U. S. HAY PRODUCTION BY ACREAGE HARVESTED, TONS PER ACRE, AND TOTAL TONS PRODUCED, 1949

Kind of Hay	Acreage Harvested	Tons Per Acre	Total Tons Produced
	Acres	Tons	Tons
1. All Hay	72,835,000	1.36	99,305,000
2. Alfalfa Hay	17,288,000	2.23	38,546,000
3. Clover & Timothy Hay	19,274,000	1.23	24,657,000
4. Grains Cut Green for Hay	2,583,000	1.15	2,963,000
5. Cow Peas for Hay	468,000	0.96	448,000
6. Wild Hay	14,918,000	0.82	12,296,000
7. Soy Beans for Hay	1,172,000	1.39	1,634,000
8. Lespedeza Hay	7,010,000	1.28	8,571,000
9. Peanuts for Hay	2,033,000	0.53	1,079,000
10. Other Hay	8,089,000	1.13	9,111,000

TABLE II

*U. S. PRODUCTION OF HAY SEED BY ACREAGE HARVESTED, BUSHELS PER ACRE, AND TOTAL BUSHELS, 1949

Kind of Seed	Acreage Harvested	Bushels Per Acre	Total Bushels Produced
	Acres		
1. Red Clover Seed	1,239,000	1.02	1,262,200
2. Alsike Clover Seed	115,500	2.97	343,600
3. Alfalfa Seed	946,200	2.00	1,895,700
4. Lespedeza Seed	1,001,000	244 lbs.	244,600,000 lbs.
5. Sweet Clover Seed	234,600	2.55	598,100
6. Timothy Seed	292,300	2.83	825,800

*Note: Hay drying equipment can be used for drying hay kept and threshed for seed. The same methods should be used as in regular hay drying. This should reduce shattering of seed, increase yields per acre, and stop sprouting or spoilage of seed before threshing.

B. INFORMATION AND EQUIPMENT FOR ELECTRICAL HAY AND GRAIN DRIER INSTALLATION

FARM STORAGE PROBLEMS

Crop production in the United States has reached an all-time peak. In spite of the fact that great progress has been made in increasing annual yields, the farm methods for preventing waste and loss of this production during harvest and storage have not kept pace. Storage and processing losses of crops held on the farm have also reached an all-time peak. It is reported that twenty-five percent of the feed value of hay is lost every year by antiquated methods of curing and harvesting. This does not take into account complete losses of hay due to severe weather conditions and spontaneous combustion. It is also reported that in 1948 farmers lost more grain during storage on their farms than was shipped to Europe under the Marshall Plan that year. Much of this loss was due to heating, molding, and insect damage, because of storage at too high a moisture content.

The present method of curing hay is approximately the same method that our ancestors used to provide feed for their livestock during the winter months. Curing methods developed centuries ago are still in use on most of the farms in the United States. The most common method is to cut the hay when the weather seems to be favorable. It then lies on the ground from three to seven days or more, until dry. It is then raked and stored in barns or in stacks, as loose chopped or baled hay. There has been considerable progress in the development of field equipment for cutting, gathering, and storing cured hay. But ninety-nine percent, or more, of the farmers still depend on good weather, a bright sun, and their ability as weather prophets to get their hay crop safely cured, just as their great-great grandparents did.

The chief problem faced by every farmer at haying time is sufficient curing of the hay to prevent spontaneous combustion. Every farmer is torn between two fears in determining when his hay should be gathered. First, he is afraid the hay may not have dried sufficiently. More than twenty to twenty-five percent mositure in the hay will cause it to heat, which may set his barn on fire and perhaps burn up all of his property, including equipment, livestock, buildings, and members of his family. The farm fire loss is $100,000,000 yearly, of which five percent is estimated to be due to spontaneous combustion. The other fear is that if he does not gather the hay soon enough loss of feed value will result because of leaf-shattering or over-drying.

Obviously, the first fear is the governing factor and most of the roughage gathered for feeding on the farm in the United States is left in the field until it is of medium or low quality. Because of its scarcity, high quality hay brings a premium price. Many farmers sell their best hay, keeping the inferior grades for home use. Poor quality feed reduces animal growth and milk production unless expensive concentrates are used to overcome the hay deficiencies.

Grain harvesting by old methods prevented most of the problems that are faced today. Before the combine and corn picker were developed it was customary to let the grain stand in the field until it ripened and dried well. It was then bound into bundles and schocked or stacked for a period of time before it was threshed or the ear corn shelled. During this period the grain was said to go into the "sweat"; that is, the moisture content was reduced by evaporation. Thus when the grain was threshed it had low enough moisture content to store

indefinitely without heating, molding, and in most cases, without excessive insect damage.

New methods and machinery have caused problems to develop that rarely had to be met in the past. Grain is now cut and threshed or picked in one operation. It is then marketed or stored immediately. Since the machines have been constructed to harvest the grain successfully at high moisture contents farmers have a tendency to gather the grain before it is ready to store. This results in excessive spoilage or a reduction in price at the grain elevator because of the high moisture content. Much grain stored on the farm has too much moisture to be eligible for Government loans. Such grain has to be marketed immediately or losses are very heavy. Recently the Food and Drug Administration sponsored legislation which will prevent the elevators and mills from buying and using grain with excess moisture and showing excessive weavil damage.

Favorable grain harvesting periods are frequently very short. This is due to the fact that rain, hail, or wind frequently shatter the grain or cause it to lodge in such a way that much of it is lost in the harvesting operation. Because of this danger farmers will always have a tendency to cut the grain before it is dry enough to store safely. Artificial drying is essential to cure the grain and prevent excessive losses.

Another problem is the change in moisture content of the grain throughout the twenty-four hour day. In the late afternoon, at night, and in the early morning the grain tends to absorb moisture, which increases its moisture content which reduces its keeping qualities. During the middle of the day, from 10:00 A.M. until 4:00 P.M., the standing grain generally has its lowest moisture content. Consequently, many farmers delay starting their harvesting in the morning until 9:00 or 10:00 and stop at 4:00 or 5:00 in the afternoon. However, those farmers who have very large grain acreages frequently start their combines very early in the morning and run them until dark, taking the chance that the loss from high moisture content will not be excessive. Most farmers will harvest from daylight until dark when bad weather threatens. These practices have definitely resulted in increased storage losses and lower prices at the elevator. Practically all of this loss can be stopped by the use of electric power to dry either grain or hay. When grain can be dried artifically, it is possible to complete harvest from one to three weeks earlier than customary.

Within the past fifteen years a great deal of research has developed and is still being done on the methods of reducing the moisture content of both hay and grain after storage. The purpose of these studies is to discover practical methods for reducing the moisture content of stored products, to stop spoilage, reduce losses, and improve the quality of products that can be harvested before drying is completed in the field. In many cases there are opportunities to use electric power to reduce loss and improve quality of farm products.

The first work done on this subject was by the TVA. The work was started as a result of the unfavorable climatic conditions in the TVA area for the customary hay curing methods. Low quality roughages in that area are due to frequent summer rains, high humidity, and cloudy weather. It was discovered that hay partially cured in the field could be completely dried in the barn. This study in crop drying came about as the result of TVA efforts to increase the growing of tame grasses and legumes for the feeding of livestock and the development of a more diversified agriculture. The chief pro-

blem was in the curing of legume hays.

Legume hays include alfalfa, lespedeza, soybeans, red clover, field pease, the vetches, and numerous other varieties which are processed for hay. In general, these plants may be characterized as having a high leaf content; this is, a large percentage of the total weight of the dried plant is leaves. The leaves in legume plants contain from two to three times as much protein, fats, carbohydrates, vitamins, minerals, and other plant nutrients as are contained in the stems. For this reason, the loss of the leaves is especially serious. Leaves are lost by shattering whenever excessive sun drying occurs or when it is necessary to turn the hay several times in curing it, because of wet weather. Few stems are ever lost; therefore, the loss in weight and food value that occurs in legume hays of good color is almost entirely from leaf loss.

Alfalfa hay that has lost all of its leaf content would have one-quarter to one-fifth of the feed value that it had when it stood in the field. It is highly important that the hay making and gathering process be designed to conserve the leaves, stop fading, and prevent rain damage. Leaves shatter when the moisture content falls below thirty-five to forty percent. As the hay gets drier, more leaves shatter during gathering and storage. Many different methods have been tried but the only successful method is to gather the hay when there is just enough moisture content in the plant to prevent the leaves from shattering. This can generally be done within four to six hours after cutting. This requires artificial drying after the hay is stored but it does eliminate practically all weather hazards and other losses, including fire.

Legume hays also contain vitamins. Color is an indication of the vitamin content. This is particularly true of vitamin A which is formed in the chlorophyll of the plant. The chlorophyll contains carotene which in turn is the carrier of vitamin A. Vitamin A is lost when the plant fades due to excessive sunlight, by repeated wetting and drying, by storage at too high a moisture content, or from oxidation during storage periods. All plants contain enzymes which are chemical agents that cause destruction of the plant cells and the vitamin content. Rapid and sufficient drying of the hay deactivates these anzymes, thus maintaining the color and vitamin content and the food value of the plant. Vitamin D is placed in the plant by sunlight both before and after cutting. The hay that remains in the field for several days would have more vitamin D than hay that is cut, raked, and stored on the same day. The loss of vitamin D because of quick removal of the hay from the field is not serious since there are generally other farm sources of vitamin D which are available to the animals, or their feed may be supplemented by fish meal or oil.

C. Crop Drying Fundamentals

The moisture content of growing plants which are cut for hay ranges from 65 percent to 95 percent. This moisture content depends on the time of year, the age of the plant, the kind of plant, and rain-fall or irrigation during the growing period immediately before cutting the crop. This means that the dry matter in the growing plant is equivalent to from one-twentieth to one-third of the total weight of the plant. The moisture content of hay is generally stated on the "wet" basis. This means that the moisture content is based on the entire weight of the plant or hay, including the moisture, at the time of the moisture determination test. Dry basis of calculating moisture content is generally used in laboratory methods or in calculating feed rations. Since the farm custom is to buy or sell hay or grain by gross weight, the moisture content is always calculated on the "wet" basis.

In drying hay for safe storage the maximum moisture content is generally considered to be 20 percent. When more than 20 percent moisture is present there is danger of the product's heating, which may result in spontaneous combustion and great fire loss. Even when heating does not result in fire there is a large loss of food value from oxidation. However, considerable enzymic reation may take place with a 20 percent moisture content. Moisture content less than 15 percent is very desirable for both grain and hay, but it is not desireable to reduce moisture contents below 10 percent. Hay having less than 10 percent moisture is very brittle and the leaves shatter very badly when the hay is moved from the barn or stack to the feed bunks. There is also some tendency for animals to injure their mouths with very dry hay. For most practical purposes artificially cured hay should have a moisture content ranging between 12 percent and 15 percent for safety and satisfactory feeding.

Extremely low moisture content may also reduce the farmer's return because it will reduce the gross weight of the hay he has to sell. It is a good plan to sell artifically cured hay on the basis of percentage of dry matter in the ton of hay or on the basis of digestible nutrients, including vitamin content. This requires a chemical analysis but it protects both buyer and seller.

In good weather the sun is very efficient in removing moisture from hay in the fields. The trouble is that farmers are seldom able to select weather of sufficient duration that the sun can shine on the hay long enouth to cure it properly. On the other hand, if the weather is good a hot sun may over-dry the hay, causing color fading and leaf shattering when the hay is gathered. Even with long-range weather forecasting it is impossible for a farmer to consistently pick weather which will guarantee him a high quality hay crop. Therefore, the plan has developed for artificial drying of hay which calls for cutting, raking, and storing in one day's time. Then air is blown through the hay until the excess moisture is removed sufficiently for safe storage.

As an example of the efficiency of the sun in removing moisture, assume that a given sample of hay contained 85 percent moisture when it was cut. In 4 to 6 hours the sun, on a bright, hot day, would remove sufficient water to reduce the moisture content of the hay to 40 percent. A ton of hay containing 40 percent moisture would then have 1,200 pounds of dry matter and 800 pounds of

water. In order to find the effectiveness of the sun it is necessary to calculate the total weight of the 1,200 pounds of dry matter and moisture before the sun started drying the hay. Since 85 percent of the freshly cut hay was moisture, then 15 percent was dry matter. Therefore, since we have 1,200 pounds of dry matter, the weight of the green hay that supplied this 1,200 pounds of dry matter totalled 8,000 pounds. In other words, the sun removed 6,000 pounds of water to change 85 percent moisture content hay to one ton of 40 percent moisture content hay.

If we then put this hay in the barn and dry it to a moisture content of 15 percent, it will then contain only 211 pounds of moisture and have a storage weight of 1,411 pounds. Thus the air blown by the fan used in the hay drier would have to remove 589 pounds of water to make the ton of hay at 40 percent moisture safe for storage. After completion of drying the one ton of 40 percent moisture hay would weigh only 1,411 pounds.

Perhaps if the problem were stated differently it could more readily be seen that the amount of moisture to be removed by the fan is generally about 10 percent of the total moisture removed from the hay. If the moisture content of the barn-dried hay is 12 percent then one ton of hay would contain 240 pounds of moisture and 1,760 pounds of dry matter. The 1,760 pounds of dry matter was originally only 15 percent of the green hay having 85 percent moisture. Then $\frac{1,760}{.15} = 11,733$ pounds which is the original weight of the freshly cut hay before drying began. This means that a total of 11,733 - 2,000, or 9,733 pounds of moisture had to be removed from the hay to reduce it to one ton of hay at 12 percent moisture content. If the moisture content of the hay was reduced to 40 percent in the field, then the sun would remove 8,800 pounds of the water. That is, 100 - 40 = 60 percent of the weight of 40 percent moisture hay is dry matter and $\frac{1,760}{.60} = 2,933$ pounds is the total weight of hay and moisture at 40 percent moisture content. The 11,733 - 2,933 = 8,800 pounds of moisture removed by the sun. Two thousand, nine hundred thirty-three pounds of hay with 40 percent moisture would then be gathered from the field and dried to one ton of weight in the barn. This would require the removal of 933 pounds of water which is equivalent to 9.4 percent of the original moisture which had to be removed by the fan.

As a general rule we can say that less than 5 percent of the original moisture in the freshly cut green plant remains in dried hay that can be safely stored. In the above case, 240 pounds of moisture that remains in the dry hay at 12 percent moisture content is equivalent to only 2.4 percent of the original moisture in the hay when it was cut. The sun was made to remove 88.2 percent of the water from the hay while it remained in the swath for a period of 4 to 6 hours. The fan removed 9.4 percent of the original moisture during the barn-curing period.

The above calculations show the quantity of moisture removed but they do not indicate the effect of temperature and humidity on the rate of drying or the time required to dry the hay completely after it is stored in the barn. This time depends on the air temperature, relative humidity, and the quantity of air blown. Air at less than 60 degrees Fahrenheit does not remove the moisture from the hay in any appreciable quantity. This is due to the limited ability of cool air to absorb moisture. As the air temperature rises, its ability to absorb moisture greatly increases. Consequently, the relation of air temperature and its moisture content at any time in the drying period is of considerable importance. This is known as the relative humidity of the air.

If the relative humidity is low, even though air temperature approaches 60 degrees, there will be some evaporation of moisture from the hay. If the relative humidity is high there will be little drying of hay even though the air is quite warm. One hundred percent saturation of the air is considered to occur during rainfall, during heavy fogs, or when ground mists in river bottoms or at night are heavy. Air blown into the hay under such conditions will add moisture to the hay rather than remove it. If the fan is not shut off during periods of high relative humidity, the hay tends to mold badly, fading occurs, oxidated enzymes become more active. Heating does not occur because the exchange of air removes any heat that might develop from increased oxidation.

All these conditions tend to lower the quality of the hay and reduce its feeding value. Therefore, there is little point in operating the blower fan to dry hay or grain unless the relative humidity is low enough to cause the air to absorb water from the hay or grain. The only exception to this rule is when poor drying conditions exist for a long period of time. Under such circumstances the blower fan should be operated one hour out of every four hours to remove any heat that may form in the hay or grain.

D RELATIVE MILK PRODUCTION PER ACRE OF FORAGE (INCLUDING OTHER FEEDS) BELTSVILLE, 1947

Forage	Alfalfa dry matter Preserved	Alfalfa dry matter Consumed per 100 pounds of milk produced	Relative Milk Production
	Percent	Pounds	Percent
Barn-cured hay------	151.5	41.4	148.2
Silage-------------	142.7	41.2	140.3
Field-cured hay----	100.0	40.5	100.0
*Dehydrated hay----	159.9	43.3	149.6

*Note: Few farmers have need for dehydrator on their farms and capital investment prohibitive except on commercial installations.

Taken from page 10, Relative Efficiency of Four Methods of Harvesting and Preserving Forage Crops for Dairy Feed.

E DRY MATTER AND MOISTURE WEIGHT PER TON FOR VARIOUS MOISTURE CONTENTS IN HAY

	At 85% Pounds	At 60% Pounds	At 40% Pounds	At 30% Pounds	At 20% Pounds	At 10% Pounds
Wt. Moisture per Field ton	1,700	1,200	800	600	400	200
Wt. Dry Matter per Field ton	300	800	1,200	1,400	1,600	*1,800
Wt. Moisture to be removed to produce 10% Hay	1,667	1,112	667	445	223	None
Wt. Green Hay to make 1 Ton 10% Cured Hay	12,000	4,500	3,000	2,577	2,111	2,000
Wt. of Moisture to be Removed	10,000	2,500	1,000	577	111	None

* Very difficult to obtain low moisture content in field of cured hay.

F POUNDS WATER PER TON OF HAY REMOVED BY THE SUN AND BY THE DRIER IN MAKING A TON OF 10% MOIST ALFALFA HAY AT VARIOUS MOISTURE CONTENTS

Hay	% Moisture in Plant When Gathered	Pounds Water Removed by the Sun	Pounds Water Removed by the Drier to make 10% Hay
Green Hay	85%	None	10,000 lbs.
Partly Cured Hay	60%	7,500 lbs.	4,500 lbs.
Partly Cured Hay	50%	8,400 lbs.	1,600 lbs.
Partly Cured Hay	40%	9,000 lbs.	1,000 lbs.
Partly Cured Hay	30%	9,429 lbs.	571 lbs.
Partly Cured Hay	20%	9,750 lbs.	250 lbs.
Well Cured Hay	10%	*10,000 lbs.	None

*NOTE: Very difficult to make 10% hay of good quality by sun curing only.

G. POUNDS OF LEAVES LOST PER TON OF HAY WITH VARIOUS LEAF CONTENT

% Leaves	Pounds Leaves	Pounds Stems	Pounds Leaves Lost
50%	1,000 lbs.	1,000 lbs.	None
#1 - 40%	800 lbs.	1,200 lbs.	400 lbs.
#2 - 25%	500 lbs.	1,500 lbs.	1,000 lbs.
#3 - 10%	200 lbs.	1,800 lbs.	1,600 lbs.
U. S. Sample			

Alfalfa Hay — Pounds Food Elements Lost per Ton of Hay with Various Leaf Content

Grade	Protein	Fat	Fibre	N. Free Extract	Mineral Matter
#1 Very leafy very green	None	None	None	None	None
#1-40% leaves	58.73	10.86	51.41	146.61	38.01
#2-25% leaves	201.82	27.15	128.51	365.53	95.03
#5-10% leaves	322.90	43.44	205.62	586.44	152.04

H. MINERAL AND FEED CONTENT OF ALFALFA HAY
CALCULATED FROM DATA OBTAINED
FROM MORRISONS FEEDS AND FEEDING

Alfalfa Hay . Pounds of Minerals Per Ton

Grade	Leafiness	Color	Foreign Material	Calcium	Phos-phorous	Potassium	Magnesium	Iron	Manganese	Digestible Protein	Energy Factor
#1-Very Leafy, Very Green	50%	65-85%	5%	30.2	4.1	42.7	6.6	6.490	387.0*	201	54.2
#1	40%	60%	5%	27.60	3.96	43.00	6.34	0.452	333.6*	176.8	53.82
#2	25%	35%	10%	23.4	3.75	43.45	5.90	0.395	253.0*	140.5	52.65
#3	10%	10%	15%	19.16	3.54	43.90	5.48	0.338	173.4*	104.2	51.42
US Sample											

POUNDS MINERALS AND PERCENT MINERALS LOST PER TON OF HAY

Barn-Cured Hay	Total Minerals, Ton	Calcium	Phosphorous	Potassium	Magnesium	Iron	Manganese	Digestible Protein
50% Leaves	471.09#	None	None	None	None	None	None	None
#1 - 40% Leaves	408.93#	8.88# 24%	0.96% 19%	8.24% 16%	16# 20%	0.136# 23%	130.8# 28%	64.4 25%
#2 - 25% Leaves	230.40#	22.20# 48%	2.4# 38%	20.6# 32%	4.0# 40%	0.84# 42%	327# 56%	301.5# 53%
#3 - 10% Leaves	246.25#	35.52# 64%	3.84# 51%	32.96# 42%	6.4# 53%	0.544# 61%	523.2# 75%	257.6 71%

* Only small quantities needed to supply animals.
Note: Taken from Page 1086, Table 1, Morrisons Feed and Feeding 21st Edition, as a result of leaf loss.

I. PERCENT MINERAL AND FEED VALUE OF ALFALFA WITH VARIOUS LEAF CONTENT VS CONCENTRATLS AND GRAIN FEEDS

FEED	CALCIUM	PHOSPHOUS	POTASSIUM	SODIUM	CHLORINE	SULPHUR	MAGNESIUM	IRON	MANGANESE	COPPER	DRY MATTER	DIG. PROTEIN	*NET ENERGY PER 100 LBS.	FEED VALUE CONSTANTS CONST. FOR CORN	FEED VALUE CONSTANTS FOR SOY BEANS	NET ENERGY FACTOR
ALFALFA 1/10 BLOOM	1.26%	0.22%	2.01%	0.14%	0.34%	0.27%	0.23%		12.3%		90.5	10.3	41.1	0.293	0.225	51.3
ALFALFA LEAVES	2.22%	0.24%	2.06%				0.40%	0.034%	32.7%		92.3	16.1	47.1	0.199	0.397	58.8
ALL STEMS	0.82%	0.17%	2.21%				0.26%	0.015%	6.0%		90.9	4.0	40.5	0.485	0.022	50.6
BONE MEAL	23.05%	10.22	0.23%	0.74%	0.09%	0.17%	0.24%	0.018%								
#3 CORN	0.02%	0.27%	0.27%	0.01%	0.06%	0.12%	0.10%	0.003%	2.5%	1.8%	8.35	6.5	78.6	0.981		98.1
COTTON SEED MEAL 45% PROT.	0.22%	1.13%					0.55%	0.018%	9.3%	11.1%	*43% PROTEIN 92.7	36.4	76.9	0.003	0.978	96.0
ALL FISH MEAL	4.14%	2.67%	0.40%	0.18%,	0.41%		0.32	0.043%	13.5%	5.6%	92.9	56.2	72.8	0.690	1.633	90.9
SOY BEAN MEASURE 45% PROTEIN	0.13%	0.68%	1.92%					0.014%	13.9%	6.3%	90.0	37.2	78.4		1.000	97.9
TANKAGE 50% PROTEIN	6.37%	3.23%	0.46%				0.70%	0.231%	10.0%	19.8%	93.5	43.6	66.4	0.385	1.240	82.9
WHEAT BRAN	0.14%	1.29%	1.23%	0.06%	0.04%	0.21%	0.59%	0.019%	51.5%	5.3%	90.1	13.7	57.1	0.426	0.293	71.3
MEAT SCRAPS 50% PROTEIN											93.9	41.8	64.6	0.355	1.187	80.6

NOTE: PAGE 1135, TABLE 11, MORRISONS FEEDS AND FEEDING, 21ST EDITION
TABLE 1, PAGE 1087

J. CALCULATED FROM MORRISONS FEEDS AND FEEDING 21ST EDITION

POUNDS FOOD ELEMENTS IN A TON OF ALFALFA HAY

Grade	Dry Matter	Lb. Leaves Per Ton	Lbs. Stems Per Ton	Lbs. Leaves Lost	Digestible Protein	T. D. N.	Nutritive Ratio	Protein	Fat	Fibre	N. Free Extract	Mineral Matter	Calcium	Phosphorous	Nitrogen	Potassium
Very Leafy Very Green (50% leaves -25% fibre)	90.5	905	905	None	228.06	953.87	3.2	294.12	38.01	682.38	682.36	156.56	27.42	3.70	47.06	38.64
#1 - 40% leaves	90.5	724	1086	362	182.45	901.38	4.55	272.22	34.73	508.96	672.23	149.87	24.97	3.58	43.55	38.92
#2 - 25% leaves	90.5	452.5	1357.5	905	149.33	828.08	5.8	239.36	29.86	571.96	557.03	139.82	21.18	3.32	38.28	39.32
#3 - 10% leaves	90.5	181	1629	1448	116.20	783.992	6.5	206.52	24.97	634.95	642.83	129.78	17.38	3.20	33.01	39.73
1/10 bloom alfalfa - 45% leaves	90.5	814.5	985.5	171	166.50	935.77	3.6	282.16	36.26	494.24	663.71	142.54	22.74	3.98	44.34	38.55
Clover less than 25% fibre	88.1	705.5	1057.2	352.4	160.34	962.05	5.0	236.11	54.62	415.83	718.90	126.86	8.11	1.23	11.63	5.30
Lespedeza before bloom	89.1	802.	980	396	115.83	836.95	6.3	229.06	47.57	399.97	757.66	112.77	16.69	2.80	31.40	17.22

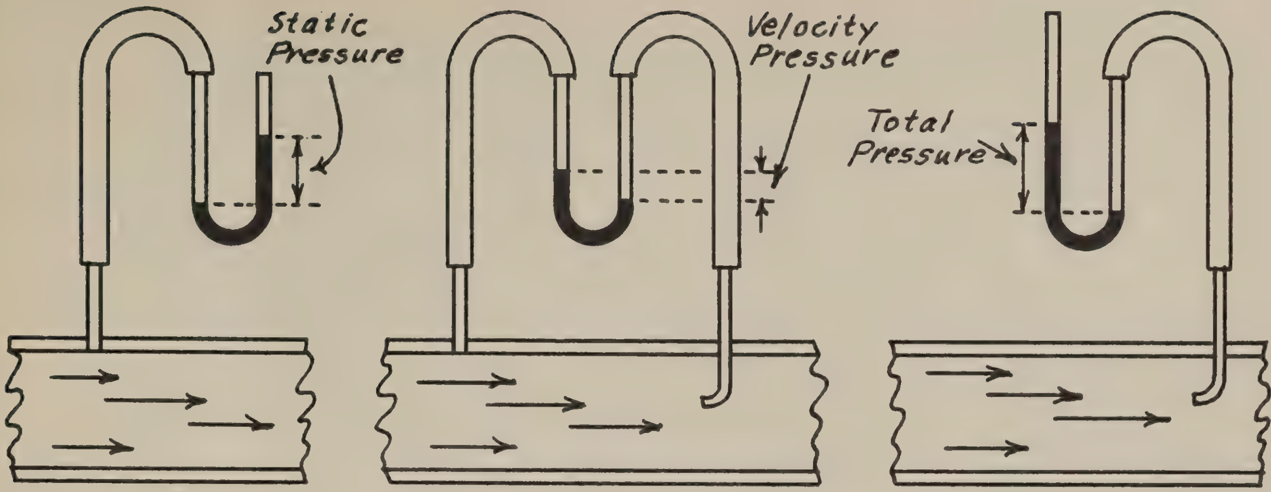
* Assume half of weight of alfalfa standing in field is leaves

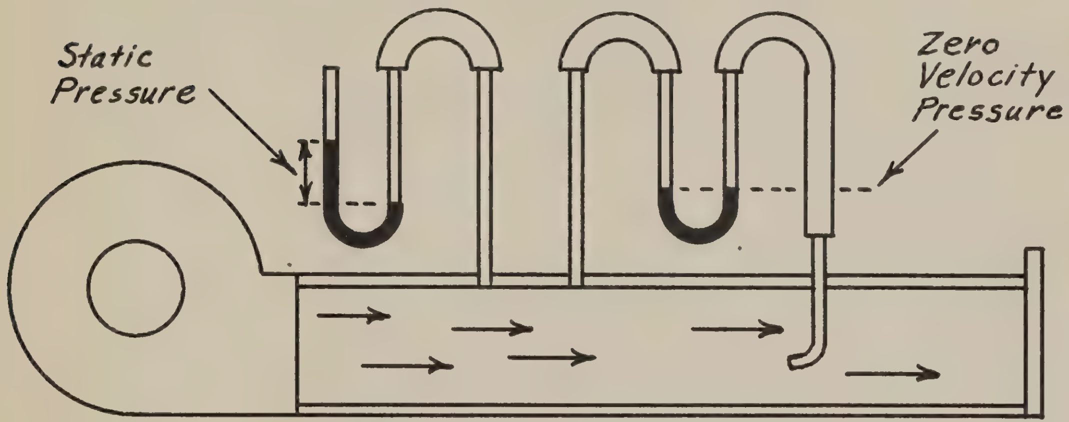
K AIR VOLUMES, VELOCITIES, PRESSURES
TEMPERATURES AND HUMIDITIES

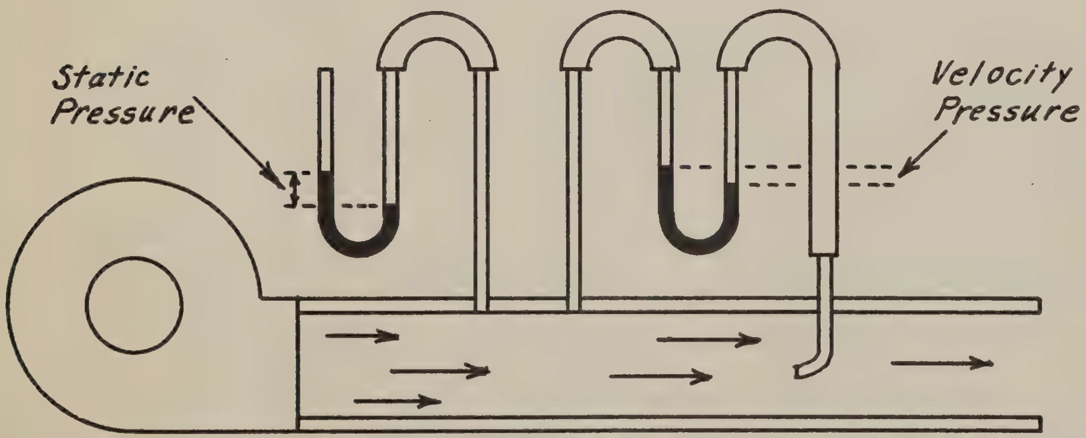
I. Air Volumes
   A. Recommended Quantities Vary
      1. Grain Drying
         A. Maximum - 10 cfm per bushel
         b. Minimum - 1/2 cfm per bushel
      2. Hay Drying
         a. Maximum - 25 cfm per sq. ft. of drier floor area
         b. Minimum - 15 cfm per sq. ft. of drier floor area
            (1) Original TVA Minimum 10 cfm per sq. ft. of Drier Floor Area
            (2) Too Little Under Adverse Conditions
            (3) Probably Satisfactory Under Ideal Conditions
            (4) Minimum Design Recommendations
               (a) Loose Hay - 15 cfm per sq. ft.
               (b) Chopped Hay - 20 cfm per sq. ft.
               (c) Baled Hay - 25 cfm per sq. ft.
   V. Drying Time vs. Air Volume
      1. Grain Drying
         a. Less Time Required as Air Flow Increases
         b. Volume Limited Due to
            (1) Depth of Grain
            (2) Kind of Grain
            (3) Back Pressure Developed
            (4) Horse Power and Type of Fan
      2. Hay Drying
         a. Time for Drying Decreases as Air Flow Increases
         b. Volume Limited by
            (1) Loose, Chopped or Baled Hay
            (2) Depth of Hay
            (3) Size of Drier
            (4) Back Pressure Developed
            (5) Horse Power of Motor and Type of Fan

II. Air Velocities
   A. Main Duct Air Velocity
      1. Maximum 1,600 feet per Minute
      2. Design for 1,000 feet per Minute
         a. Air Flow Variable
         b. Permits Increased Volume When Necessary
   B. Lateral Duct Air Velocity
      1. Maximum 1,600 CFM
         a. Better Less than Main Ducts
         b. Lateral Velocities to 3,000 CFM Have Been Found (Not Desirable)
      2. Slatted Floor System
         a. Consider as a Wide Duct
         b. Calculate Velocity on Basis Air Entrance Area

C. Design of Ducts for Air Velocity
   1. Use Fan Capacity
      a. At Assumed Air Pressure
      b. At Main Duct Entrance
   2. Main Duct Width
      a. Same as Fan Width
      b. Wider if Necessary
      c. Adjust Height and Width to Control Air Velocity
   3. Main Duct Height
      a. Same as Fan Discharge Opening
      b. Higher if Necessary
      c. Adjust Height or Width to Control Air Velocity
   4. Calculations
      a. Multiply Width x Height of Main Duct at Fan Entrance
      b. Divide Required Air Volume for Drier by (a), Cross Sectional Area of Main Duct at Fan
      c. This equals Air Velocity at Main Duct Entrance
      d. If Air Velocity Too High
         (1) Increase Designed Height or Width of Main Duct
         (2) Multiply New Height x New Width (This is Cross Sectional Area)
         (3) Again, Divide Required Air Volume by (2), Cross Sectional Area
         (4) Repeat Until Desired Air Velocity is Obtained
   5. Taper Main Ducts
      a. To Maintain Pressure at Large End
      b. To reduce Velocity Pressure Effect
      c. To Cause Uniform Air Discharge into Lateral Ducts or Slatted Floor
      d. Reduce Cross Section of Main Duct Equal to Total Area of Laterals as Served
      e. Use Vertical or Horizontal Taper as Desired
   6. Lateral Ducts
      a. Total Cross Section of Laterals Should Equal Main Duct Cross Section at Fan
      b. Check to See Main Duct has Cross Section at Any Point Equal to Total Cross Section Area of Lateral Beyond That Point
      c. Keep Velocity in Laterals Less Than in Main Duct if Possible
   7. Air Velocity Through Hay
      a. Determined by Air Volume
      b. Area Exposed to Air
      c. Exterior Area of Hay on Drier From which Air Can Escape
      d. Velocities of 2' per Second Through Baled Hay have been Measured


Static Pressure
Velocity Pressure
Total Pressure


Static Pressure
Zero Velocity Pressure


Static Pressure
Velocity Pressure

III. Pressures in Driers
- A. Very Low Compared with Water Pressure in Farm Water Supply System
  1. Measure by "Inches of Water"
  2. (i.e.) Height of Column of Water That can be Raised by the Air Pressure
- B. Static Pressure
  1. Not Due to Movement of Air
  2. Caused by Compressing Large Volume of Air into Small Space or Chamber
  3. Exerted Against Sides, Top, Bottom and Ends of Ducts
  4. Low in Hay Drier
     - a. Varies from 1/2 Inch to 2 Inches of Water
     - b. Equals 0.3 of an Ounce to 1.2 Ounce per sq. in.
  5. Measured by a "U" Tube
  6. Caused by Resistance of Drier to Air Flow
  7. Fans are Rated by Volume of Air They Will Deliver Against Given Static Pressure
  8. Grain Driers Need Greater Air Pressure
     - a. Two to 5 Inches of Water
     - b. Special Type Fans Needed for Pressures over 2 Inches
- C. Velocity Pressure
  1. Due to Air Movement
     - a. Speed of Air
     - b. Weight of Air
  2. Taken by a Tetot Tube and Measured by a "U" Tube
  3. Exerted Against End of Duct and Top or Sides of Taper Ducts
- D. Total Air Pressure
  1. Sum of Static and Velocity Pressure
  2. Since Some Air Escapes, Velocity Pressure Needs Thicker Air Seal at End Opposite Fan in Stack Driers
- E. Conversion of Static and Velocity Pressures
  1. When Air Flow Stops, Velocity Pressure is Converted to Static Pressure
  2. Static Pressure Converted to Velocity Pressure When Air Escapes

IV. Air Temperature
- A. Normal Temperature Air
  1. Satisfactory above 60° F.
  2. Below 60° F.
     - a. Unsatisfactory for Drying
       - (1) Because of Low Water Holding Capacity
       - (2) Natural Humidity Generally Too High for Drying Without Heat

B. Heated Air
  1. Use Oil in Most Cases
  2. Increase Temperature of Air
    a. For Hay Drying $\neq 20^\circ$ F.
    b. For Grain Drying
      (1) For Seed Grain, Maximum 110° F.
      (2) For Feed Grain, Maximum 130° F.
      (3) For Wet Milling, Maximum 130° F.
  3. High Moisture Content in Grain Requires Heated Air
    a. Above 28% Heat Essential
    b. Air Temperatures below 50° F. Require Heat
  4. Decreases Drying Time
      a. Increases Annual Capacity of the Drier
      b. Prevents Spoilage During Winter Due to Warm Days

V. Air Humidities
  A. Water Holding Capacity of Air
    1. Varies with Air Temperature
    2. Warm Air Holds More Water Tahn Cold Air
  B. Expressed as Relative Humidity
    1. Measured by Wet and Dry Bulb Thermometers
    2. Tables Show Relative Humidity from the Two Readings
    3. Changes Rapidly with Temperature Variation
  C. Humidities Generally Found
    1. During Rain, Fog, Heavy Mist - Relative Humidity - 100%
    2. Cold Weather - Relative Humidity Increases
    3. Stop Fan When
      a. Relative Humidity Above 70% to 80%
      b. When Air Temperature Drops Below 60° F. for Hay Drying
      c. Especially During Last Third of Hay Drying Period
      d. When Air Temperature Drops Below 50° F. for Grain
  D. Operate Fan Intermittently
    1. One Hour out of Four
      a. To Remove Heat
      b. To Prevent Adding Moisture to Hay or Grain
    2. Very Important During Last Third of Drying Period
    3. When Air Temperature Too Low
    4. When Humidity Too High

L AIR DISTRIBUTION SYSTEM

I. Types of Duct System
   A. Center Main Duct
      1. On Barns to 40 Feet Wide
      2. Where Fan and Motor Can Supply Whole New Floor Area
      3. Total Depth Hay Not Over 16 Feet
      4. Fan and Motor Can be Located at End of Barn
   B. Side Main Duct
      1. For Mows Less Than 30 Feet Wide
      2. To Get Main Duct Out of Way
      3. When Main Duct Can be Put in Side Shed
   C. Divided Main System
      1. Where Fan and Motor Cannot Be Located at End of Barn
      2. Where Mow Floor Area is Too Large for Capacity of Fan and Motor
      3. Where Cuttings of Hay are not Large Enough to Cover Entire Drier
      4. When Two Kind of Hay are to be Cured Separately
   D. Use One or More Main Systems
      1. Connect Them to a Single Air Supply Duct
      2. When Barn is More Than 40 Feet Wide
      3. Where Hay Chute Openings, Posts, or Other Obstructions Prevent Use of Single Main Duct

II. Parts of a Duct System
   A. Fan Room with Air Inlet
   B. Main Duct
   C. Lateral Ducts
   D. Air Escape Openings in Sides, Ends or Roof of Barn

III. Main Duct Design
   A. Same Width as Fan Discharge Opening, or Wider
   B. Same Height as Fan Discharge Opening, or Higher
   C. Increase Width or Height or Both as Necessary
      1. To Keep Air Velocity Near 1,000 Feet Per Minute
      2. Divide Required C.F.M. of Air for Drier by 1,000
         a. Result is Desirable Cross Sectional Area of Main Duct in Square Feet
         b. Multiply Assumed Width and Height of Main Duct to get Trial Cross Sectional Area
         c. Increase Proposed Width or Height of Main Duct if Necessary
         d. Taper Main Duct
            (1) Vertically - or
            (2) Horizontally
            (3) To Height or Width of 18" or 24" as Necessary

d. Taper Main Duct (continued)

(B). To Height or Width of 18" or 24" as Necessary (continued)

(a) To Provide Area Equal to Total Cross Sectional Areas of Lateral Ducts Served Beyond any Point in Main Duct

(b) Purpose of Tapering Main Duct

(1.1) Overcomes Effect of Air Velocity Reducing Air Pressure Near Fan

(1.2) Maintains More Uniform Total Pressure Throughout Duct

E. Air Vents in Main Duct

1. For Lateral Ducts

a. Space 4 Feet Apart on Centers

b. At Floor Level

c. Size to Fit

(1) Cross Section of Lateral

(2) To Fit Length of Lateral

(a) Where Laterals are Very Long

(b) Where Laterals are Very Short

(c) Calculate on Base Square Footage Served by Lateral

2. On Top of Main Duct

a. Where Duct is More Than 3 Feet Wide

b. Space Vents Half Way Between Lateral Ducts

c. Make Vents One Inch Wide

(1) By spacing Top Cover Boards

(2) Cover With Spreader Board

(a) Six to 8" Wide

(b) Mounted on 1" Cleats

d. Purpose

(1) To Disperse Air Through Center of Drier

(2) To Prevent Heat Developing

(3) Not Used on Side Main Duct

F. Stop Main Duct Five Feet From End of Drier

1. To Cause Hay to From Air Seal

2. Place Last Pair Laterals at End of Main Duct

G. Underground Main

1. For Use in Hay Barns

2. Purpose

a. Saves Hay Storage Space

b. Gets Duct Out of Way

c. Permits Other Use of Building

3. Taper of Underground Main

a. By Depth of Excavation

b. Maintain Uniform Width

c. Line With Concrete

d. Cover

(1) With Concrete

(2) With 2" Boards

e. Use Air Escape Ports

(1) For Laterals

(2) Located in Top

IV. Lateral Duct Design
- A. Space 4 Feet on Centers
- B. Size of Lateral Ducts
  - 1. Total Cross Section of Lateral Ducts Equal
    - a. Cross Section of Main Duct
      - (1) At Fan End of Main
      - (2) At Any Point Along Main Duct
    - b. Proportionate to Length of Laterals
  - 2. Cross Section of Laterals
    - a. Six Inches by 10 Inches
    - b. Vary as Necessary
      - (1) Eight Inches by 12 Inches
      - (2) Other Dimensions as Needed
- C. Stop Lateral Ducts
  - 1. Fifteen Feet From Sides of Barn
  - 2. Five Feet From Any Opening
  - 3. Five Feet From Any Post
- D. Taper Laterals
  - 1. When Lateral Longer Than 12 Feet
  - 2. Make Lateral in 8' to 12' Sections
  - 3. Taper by Section or Uniformly
- E. Air Escape Ports
  - 1. Crack 1" Wide at Bottom
    - a. Place Lateral on 1" Cleats
    - b. Space Cleats 4' to 6' Apart
  - 2. Bored Holes
    - a. Size $1\frac{1}{2}$" - Diameter
    - b. Spaced 7" to 8" Apart
    - c. Place on Sides and Top
      - (1) Double Rows Used
      - (2) Use Air Spreader Board on Top
    - d. Not Desirable
      - (1) Requires Too Much Labor
      - (2) Air Escape Area Limited
      - (3) Holes May Become Plugged

V. Slatted Floor System
- A. Use Main Duct
  - 1. Design Same as for Duct System
  - 2. Can be Placed Above or Below Ground Level
  - 3. Use Same Maximum Air Velocity
  - 4. Have Continuous Air Escape Port on Sides at Bottom on Duct
- B. Slatted Floor Design
  - 1. Make In Sections
    - a. 4 x 8 to 6 x 10 Feet Sizes
    - b. For Easy Handling
    - c. To Remove for Cleaning Floor

2. Construct on Sills
    a. Size 2 x 6 or 2 x 4 Feet
    b. Sometimes 1 x 6 or 1 x 4 Feet Suitable
    c. Space 2 Feet on Centers
3. Slat Material
    a. Size 1 x 3 Inches
    b. Space 3/4 Inch to 1 Inch Apart
4. Taper Slatted Floor
    a. By Reduction of Width of Sills
    b. Make Taper by Sections
        (1) Next to Main Duct, Use 6 or 8 Inch Sills
        (2) Center or Outside Sections on 4 Inch Sills as Desired
5. Space Seal Required for Slatted Floors
    a. For Baled Hay, Stop Floor 2 or 3 Feet From Ends and Sides of Drier Area
    b. For Chopped Hay, Stop Floor 4 Feet From Ends and Sides of Drier Area
    c. For Loose Hay, Stop Floor 5 Feet From Ends and Sides of Drier Area

M TYPES OF BLOWER FANS AND THEIR OPERATING CHARACTERISTICS

1. Centrifigual Blower Fans
2. Propeller Blower Fans
3. Vane Axial Blower Fans
4. Tube Axial Blower Fans

I. Types of Blower Fans
   A. Centrifigual Fans
      1. Forward Curved Blades
         a. Single Unit
         b. Double Unit
      2. Backward Curved Blades
         a. Very Heavy Construction
         b. Too Expensive for Most Farm Installations
         c. They are Designed for Industrial Use
   B. Blower Fans
      1. Airplane Type
         a. Two Blades
         b. Satisfactory if Available
      2. Multiblade Propeller
         a. Older Types
            (1) Six Blades
            (2) Developed Pressures to 2 Inches of Water
         b. Newer Types
            (1) Seven Blades
            (2) Develop Pressures to 5 Inches of Water
            (3) Volume Drops Rapidly as Pressure Increases Above $1\frac{1}{2}$ Inches of Water
            (4) Maximum Listed Capacity at 1/2 Inch of Water
      3. Vane Axial Fans
         a. Build Higher Pressures in Smaller Sizes
         b. Due to Action of Vanes
            (1) Reduce Their Turbulence
            (2) Straighten Air Flow
            (3) Prevent Backward Leakage of Air and Dissipation of Pressure
            (4) Are More Efficient
      4. Air Foil Blades
         a. Have Curved Surfaces
         b. Thicker Edge Leads
         c. Thin Edge Trails
         d. May Make Less Noise
         e. May be More Efficient

II. Blower Fan Operating Characteristics

A. Forward Curve Blade Fans

1. Low Speed - (i.e.) Less than 1,000 RPM
2. Low Pressure (i.e.) Less than 1½ Inches of Water
3. Wide Range of Volume with Small Change in Back Pressure
4. Will Overload Motor
   a. Air is Heavy
   b. Large Volume Change Increases Weight of Air Moved and Overloads Water
   c. Motor Must Have Overload Protection
      (1) Internal or Current-Limiting Control
      (2) Ammeter to Indicate Load on Motor at Anytime (Can be Installed) (in Motor Starter Box)
5. Fan Should Be Equipped with Adjustable Exhaust Damper
   a. To Regulate Back Pressure
   b. To Maintain Uniform Load on Motor
   c. Prevents Motor Burn-Outs
   d. Prevents Motor Stoppage by Thermostat on Other Control
6. Air Outlet Velocities - 1,600 to 2,500 Feet Per Minute at 0.5 to 1.0 Inches of Water
7. Fans Built in Two Weights
   a. Light-Gage Metal (for farm driers)
   b. Heavy-Gage Metal (for commercial installation)
8. May be Obtained in
   a. Single Widths
   b. Double Widths (i.e.) Two Single Units on one Shaft
9. Vary Fan Speed by
   a. Using Two-Drive Pulleys on Motor
      (1) One for Low Pressure (i.e.) 0.5"
      (2) One for Higher Pressure (i.e.) .75"
   b. By Using Two Sizes of "V" Belts
      (1) A Section Belt for 0.5"
      (2) B Section Belt for .75"
   c. For Volume and Pressure Required

B. Backward Curve Blade Fans

1. Higher Speed For the Forward Curve Fans
2. Built of Heavy-Gage Metal Only
3. Smaller Change of Volume with Wider Range in Back Pressure
4. Will not Overload Motor with Pressure Changes Encountered in Farm Driers
5. Available in Single Units Only
6. Disadvantage for Use in Farm Driers
   a. Heavy Weight
   b. Larger Sizes
   c. Higher Cost

7. Vary Fan Speed as Necessary for Pressure and Volume Required (Use Pulleys)

C.. Propeller Blade Fans

1. High Speed 1,500 to 2,000 RPM
2. Constant Speed (Preliminary)
3. H.P. Demand Almost Constant
4. Low Volume with Maximum Resistance
5. Higher Efficiency than Centrifugal Fans at Low Pressures
6. Noisy, Due to Top Speed

D. Vane Axial Fans

1. High Efficiency
2. Wide Range of Pressure with Little Volume Change
3. Slower Speed (About 2/3 of High Speed Propeller Fan)
4. Quiet or Noisy Depending on System Where It is Operating
5. Less Noisy Than Propeller Fans

E. Tube Axial Fan

1. A Propeller Fan in A Tube
2. Tube Straightens Air Flow
   a. As air approaches fan
   b. As air leaves fan
3. Characteristics Similar to Vane Axial Fan
4. Available Information Limited at Present

N. BUILDING MODIFICATION

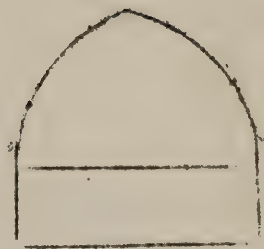
I. Building Modification for Hay Driers

A. Types of Roofs Limit Design
(Weather-proof Roof Essential)

1. Gable Roof

2. Gambrel Roof

3. Gothic Arch



4. Shed Roof

5. Quonset Roof

B. Hay Loft or Mow Installations

1. Check Hay Loft Floor

a. Must be Airtight Floor

(1) Tongue and Groove Material Best

(2) Cover all Knotholes or Large Cracks with Sheet Metal

(3) If Necessary, Cover Floor with Heavy Building Paper

(4) Close All Unnecessary Openings
(5) If Possible, Close All Openings in Hay Drier Floor Area
(6) Make New Openings Outside Hay Drier Floor Area If Necessary
(a) For Stairways
(b) For Hay Chutes
(c) Place New Openings for Convenience

2. Check Air Escape Areas
a. Have five times as much Air Escape as Air Inlet Area. More Desirable
(1) Open Large Double Hay Doors During Drying
(2) Open Cupola
(3) Open Dormer Windows
(4) Cut New Escape Openings
(a) Protect with Louvres
(b) Place Opposite Largest Existing Opening
(1.1) To Overcome Effect of Wind Pressure
(1.2) To Reduce Distance Traveled by Escaping Air
(c) Place Above Top Hay Level
b. Velocity of Escaping Air
(1) Maximum 200 Feet per Minute
(2) Equals 1 Square Foot Air Escape Area for Each 200 cfm
c. Open-Sided Buildings Desirable
(1) Extend Siding Down Sufficiently
(a) To Protect Hay from Weather
(b) To Strengthen Building
d. Check Weight of Hay to be Stored
(1) Partially Cured Hay very Heavy
(a) May Break Down Supports
(b) Cause Building Failure
(2) Estimate Tonage of Hay to be Stored as follows:
(a) Obtain Cubic Feet Volume of Hay Storage Space
(b) For Loose or Chopped Hay
(1.1) Use 300 Cubic Feet Equal One Ton of Partially Cured Hay
(1.2) Use 350 Cubic Feet Equal One Ton Hay Cured on Drier
(c) For Baled Hay
(1.1) Use 100 lbs. per Bale for Partially Cured Hay
(1.2) Use 70 lbs. per Bale for Hay Cured on Drier
e. Check Building Supports
(1) Posts Not Over 10 to 12 Feet Apart
(2) Spans Between Beams Not Over 10 to 12 Feet Unless of Very Heavy Construction

(3) Floor Joists
(a) Check to See
(1.1) If Joists have been Broken
(a.a) By Weight of Hay
(a.b) By Curing Cracks
(a.c) Due to Knots on Bottom Side
(1.2) Dimensions
(a.a) At least 2" x 10"
(a.b) Spaced 18" to 24" Apart
(AA) Wider Spacing Not Safe

f. Notify Owner of Condition of Building in Writing
(1) Total Weight of Hay to be Stored
(2) Specify Changes to be Made before Drier is Installed
(a) New Openings
(b) Floor Covering
(c) Additional Supports
(1.1) Posts
(1.2) Beams
(1.3) Floor Joists
(3) Place Responsibility on Owner

g. For Drier Construction
(1) Check Total Floor Area of Mow
(2) Check Total Floor Area of Drier
(3) Check Clearance of Roof Above Floor
(a) At Eaves
(b) At First Break
(c) At Ridge
(4) Check at all Openings
(a) In Loft
(b) In Drier Area
(5) Check all Posts
(a) In Loft
(b) In Drier Area

II. Hay Handling Equipment for Placing Hay in Barn
A. Blower Elevators
1. For Loose Hay
2. For Chopped Hay
B. Truck and Carrier
1. For Loose Hay
2. For Baled Hay
C. Elevators and Conveyors
1. For Baled Hay
2. To Move Hay in Loft
a. From Floor to Top of Pile
b. From Place to Place in Loft
D. Hay Hoists
1. Operated by Team Tractor or Car
2. Electric Motor Powered
a. Location of Hoist
b. Size of Motor Required
c. Can Hay Drier Motor be Used for Hoisting

3. Location of Electric Hoist
    a. On Ground Level
    b. In Hay Loft
        (1) On Loft Floor
        (2) On Top of Fan Room
        (3) Other Convenient Locations

III. Air Inlet Opening to Blower Fan
  A. Location
    1. End or Side of Barn
    2. At Floor Level
    3. On Side of Prevailing Wind if Possible
  B. Sized Opening
    1. Large as Possible
      a. To Fit Fan Room
      b. Do Not Weaken Building
    2. Minimum Air Inlet Velocity
      a. 1,000 Feet per Minute
      b. Less if Possible
    3. Protect Opening
      a. With Louvres
      b. With 1/2-Inch Mesh Hardware Cloth
        (1) To Keep Birds Out
        (2) To Keep Trash From Being Sucked in by the Fan
      c. Use Existing Opening
        (1) If Properly Located
        (2) Enlarge if Necessary

O. CROP DRYER DESIGN

1. Purpose and planned usage of the dryer
    A. Kind of crops to be dried
        (1) Hay
        (2) Small grain or shelled corn
        (3) Ear Corn
        (4) Combination of above 3 products

    B. Hay drier size and type
        (1) Based on annual tonnage
            (a) Estimated yearly average
                (1) Tons
                (2) Acreage
            (b) Maximum tonnage per cutting
            (c) Minimum tonnage per cutting
        (2) Planned method of gathering and storing the hay
            (a) Full length hay
            (b) Chopped hay
            (c) Baled hay
            (d) To be cured in barn or stack
        (3) Location of drier
            (a) Hay mow or loft
            (b) Hay barn on ground floor
            (c) Outside stack type dryer
        (4) Type air distribution desired
            (a) Central main duct only
            (b) Main duct with laterals
            (c) Main duct with slatted floor
            (d) Main duct formed by bales
                (1) With slatted floor
                (2) WWith laterals formed by bales (not recommended)
        (5) Heated or unheated air
            (a) Time of year drier is operated
            (b) Temperature and climatic conditions at time of curing
            (c) Time available for curing one charge of hay

C. Small grain and shelled corn drier - size and type

(1) Based on bushels to be dried annually
  (a) During harvest
  (b) After harvest
  (c) Is drier to be emptied and used again
  (d) Maximum depth of grain
  (e) Minimum depth of grain

(2) Location of drier
  (a) Bin in a building or granary
  (b) Special grain storage bin
  (c) Outside in an uncovered pile

(3) Method of using small grain drier
  (a) Dry and store grain in same bin
  (b) Dry and move grain
    (1) To market
    (2) To other farm storage space
  (c) For grain cooling
    (1) To reduce temperature of grain
    (2) To prevent moisture migration in grain
  (d) For freezing grain
    (1) In weather too cold for drying
    (2) To hold grain over winter for drying in spring

D. Air Volume Required

(1) For hay driers
  (a) Based on method of gathering hay
    (1) Long hay
      (a) Minimum 15 cfm per square foot of drier floor area
      (b) Maximum 20 cfm per square foot
    (2) Chopped hay
      (a) Minimum 20 cfm per square foot of drier floor area
      (b) Maximum 25 cfm per square foot
    (3) Baled hay
      (a) Minimum 20 cfm per square foot of drier floor area
      (b) Maximum 25 cfm
  (b) C.F.M. required of blower fan
  (Drier area in sq. ft. X cfm per sq. ft.)

(2) For grain driers
  (a) Based on kind of grain
    (1) Ear Corn
      (a) 6 to 10 cfm per bushel
        (1) Climatic conditions govern volume of air per bushel
        (2) Moisture content of corn
        (3) Use of heat
      (b) 40 cfm per square foot of floor area is used for estimating total volume
    (2) Small grain and shelled corn
      (a) Varies from 1/2 to 10 cfm per bushel
        (1) Use of heat
        (2) Time of year
        (3) Climatic conditions
        (4) Moisture content of small grain
      (b) To prevent migration of moisture
        (1) Low volume 1/2 to 2 cfm per bushel
        (2) Intermittent usage for grain cooling

E. Air Pressure Required
  (1) For hay driers
    (a) Depends on method of gathering hay
      (1) Loose hay - 1/2 to 3/4 inches of water
      (2) Chopped hay - 3/4 to 1-1/2 inches of water
      (3) Baled hay - 1-1/2 to 2 inches of water
    (b) With proper type of fan air pressure may go as high as 5 inches of water
  (2) Ear corn driers
    (a) 1/2 inch of water to 1.7 inches of water depending on depth of corn
    (b) Most farm cribs will require less than 1 inch of water pressure
  (3) For small grain and shelled corn
    (a) Depends on depth of grain
    (b) Varies from ½ to 9 inches of water at high air volumes per bushel

P. BLOWER FAN and MOTOR SELECTION FOR CROP DRIERS

I. Power available limits motor size

A. Single phase line - Maximum 10 HP Motor

B. Multiphase line - Motor size not limited

II. Type of motor

A. Capacitor start motors
   (1) Capacitor start - induction run motors limited to 10 HP
   (2) Capacitor start - capacitor run induction motors limited to 10 HP
   (3) Repulsion start - induction run motors limited to 10 HP.
   (4) Multiphase motor - any size required

III. Type of fan to select

A. Depends on drier size and air requirements
   (1) Volume of air
   (2) Back pressure developed
   (3) Overload characteristics of fan
   (4) Objection to noise

B. Whether blower fan is to be portable or permanently installed

C. Size of motor required for quantity of air
   (1) At maximum air pressure
   (2) At minimum air pressure

D. Availability of equipment
   (1) Dealers and distributors in area
   (2) Repairs and service facilities

IV. Type of fan drive

A. Direct connection to motor
   (1) Extended shaft and coupling
   (2) Number of belts

B. V Belt Drive
   (1) Size of pulleys
   (2) Number of belts
   (3) Size of belts

V. Type of fans

A. Centrifugal fans
(1) Forward curved blades
(2) Backward curved blades

B. Axial fans
(1) Open propeller fan
(2) Tube-axial fan
(3) Vane-axial fan

Q. HAY MAKING PROCEDURE

I. When to cut hay for maximum feed value
   A. Alfalfa - 1/10 to 1/4 full bloom stage
   B. Lespedeza - When first bloom appears
   C. Soey Beans - Before seeds are 3/4 developed
   D. Clover - One-half to full bloom
   E. Timothy - Early to full bloom
   F. Johnson Grass - When heads start to emerge from root or not later than when 1/4 of the heads have appeared.

II. Limit amount of hay cut at one time
   A. To amount that can be put up in one day
   B. To capacity of drier for one charge of green hay

III. Start mower in the hay field
   A. As soon as dew is off the plants
   B. Mid-afternoon - about 4 hours before sunset
      (1) When hay is to be gathered 2nd day
      (2) So leaves will not get too dry
      (3) To get moisture down to about 45 percent before sunset.

IV. Start raking hay into windrows
   A. When moisture content checks 40 to 45 percent in first hay out
   B. On very hot dry day when moisture checks 45 to 50 percent
   C. Use field type moisture tester to determine moisture content

V. Start gathering hay from windrows
   A. When loose hay shows 40 percent moisture
   B. For Chopper - When moisture is 40 percent
   C. For Bales - When moisture is 40 percent

VI. Keep gathering hay
   A. Until enough hay is on drier to start fog
      (1) When enough air seal is formed to distribute air uniformly
      (2) When enough back pressure exhists to prevent overloading fan motor. (Especially important when a forward curve blade fan is used)
   B. Until drier is fully loaded
      (1) Do not overload drier
      (2) Depth of hay
         (a) Loose hay
            (1) 8 feet of green hay first charge
            (2) 8 feet of green hay 2nd charge
            (3) Total depth 16 feet on drier

(b) Chopped hay
    (1) 6 feet of green hay first charge
    (2) 6 feet of green hay 2nd charge
    (3) Total depth on dried 12 feet
(c) Baled hay - Tapered starch
    (1) Height 12 to 14 bales
    (2) Maximum horizontal distance of air travel 8 feet on each side of main duct.

R. Hay Placement on Driers

I. Essential to Obtain Uniform Density
A. To permit uniform air penetration
B. To prevent hot spots
C. To prevent loss of air pressure
D. To cause uniform drying

II. Maintaining Air Seal
A. Depth of hay
(1) uniform distance of air travel at all discharge openings
(2) deep enough to cause necessary back pressure
(a) to prevent overloading motor
(b) to cause uniform air flow
B. To form air seal
(1) At ends and sides of drier
(1) with loose and chopped hay
(a) 4 to 5 feet margin beyond ends of lateral ducts or slatted floors
(b) for baled hay
(1) 6 to 8 feet of hay between main duct and sides of hay drier
(2) two extra feet of hay at the end opposite the fan (to overcome effect of velocity pressure).
(2) Around posts or openings
(a) Pack loose or chopped hay tightly around posts
(b) Put collars on posts
(1) at 3 to 4 feet height from floor
(2) 6 to 12 inches around posts
(c) Close necessary floor openings with vertical siding to height of stored hay
(1) use tongue and groove lumber
(2) use building paper for lining unmatched lumber
(d) Close air escape openings in drier ducts
(1) at point 5 feet from posts
(2) at point 5 feet from necessary floor openings

III. Method of Placing Hay
A. Full length hay should be forked into place on drier by hand.
(1) Elevate into barn with:
(a) Hay Carrier - harpoon or slings
(b) Blower - Elevating type
(2) Tear all bunches of hay apart with hand for handplace
B. Chopped hay should be blown into place
(3) Baled hay
(a) place bales on wide side
(b) cross tie as they are placed in stacks
(1) in customary manner
(2) to prevent separation of poles as hay dries
(c) break joints wherever possible
(1) to prevent loss of air pressure
(2) to be stacked firmly together

(d) place bales to form main duct
    (1) 4 feet wide
    (2) 2/3 to 3/4 length of stack
    (3) about 4 feet high (i.e. 3 layers of bales sufficient)
        (a) place 2" x 6" x 8' timbers over main duct
        (b) use 2 for each bale length
        (c) cover duct with bales lengthwise of duct

(4.) Place bales to width of 8 feet each side of main duct

(e) after 3rd layer of bales is placed
    (1) draw each layer in 1/2 bale on sides and ends
        (a) purpose break vertical and horizontal joints between bales
        (b) prevent air pressure loss above duct
        (c)
    (2) prevents hay from heating in upper layers at outside edge
    (3) equalizes hay pressure
        (a) lower layers of bales pack very tightly
            (1) due to green hay
            (2) due to weight of hay above
            (3) tends to misshape bales
        (b) increased height above duct packs hay tighter equalizing hay pressure

(f) slatted floor under baled hay drier
    (1) place bales to form main duct
        (a) 4 feet by 4 feet
        (b) 2/3 to 3/4 length of drier
    (2) form air seal at floor level
        (a) by placing bales on ground or main floor
        (b) extend bales one bale length beyond slatted floor
        (c) with slatted floor
            (1) width of drier not limited to 20 feet
            (2) height limited to 8 or 10 bales with one green charge of hay on drier
            (3) total depth of 2 charges of green hay on drier limited to 12 or 14 feet
            (4) taper top layers of bales
                (a) build stack high enough to seal air above main duct
                (b) after drying replace top layers of bales to form level top of dry hay
                (c) drier then ready for second charge of green hay
            (5)
                (g) Use canvas sleeve to seal fan to main duct
                    (1) use heavy canvas 6 feet by $24\frac{1}{2}$ feet
                    (2) form a sleeve around fan housing
                        (a) extend sleeve into main duct
                        (b) fasten to hay bales with lath and #10 finish nails

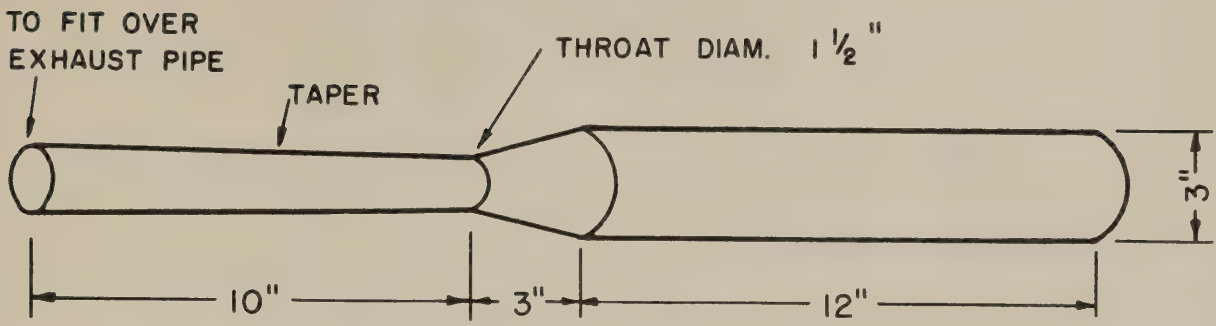
I. Field Testing Essential
   A. Because of difficulty in judging moisture content of hay accurately
   B. Use field method with practical equipment
      1. Laboratory equipment not suitable
         a. Too costly
         b. Too slow
      2. Field equipment crude but satisfactory for hay making
         a. Can be done rapidly
            (30 minutes per test)
         b. Accurate to about 5 percent
         c. Prevents gathering hay with too high moisture content

II. Method of Gathering Samples
   A. Pick several one pound samples from swath
      1. Take cross section of swath representative of hay condition
      2. Get samples 50 to 100 feet away from edges of field
      3. Do not gather samples from very low or very high spots in field
   B. Mix samples thoroughly
      1. Divide to get representative sample
      2. Use about 100 grams of partially dried hay (Note you will soon learn about how much hay to use for a test)
         a. More than 100 grams takes too long to dry
         b. Less than 100 grams dries too rapidly
         c. Small samples give less accurate test
         d. <u>Do not try to use scale that weighs in ounces</u>

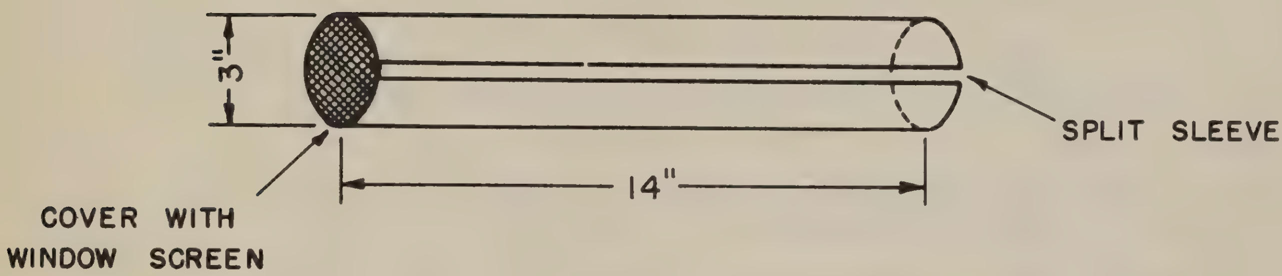
III. Types of Suitable Hay Moisture Testers for Field Use
   A. Car Exhaust Method
      1. Three inch cylinder with elongated stem which fits over car exhaust pipe
      2. Split sleeve holds hay sample
         a. Fits in main cylinder
         b. Cover one end of aplit sleeve with window screen
            (1) Prevents loss of leaves during test
            (2) Permits speeding engine in latter stage of drying sample
      3. Requires druggist scales that weigh in grams
         a. Use 100 gram hay sample for the moisture test (approximate weight)
         b. Calculate moisture content on wet basis (i.e. Weight of moisture lost divided by original green sample weight)

EXHAUST PIPE MOISTURE TESTER

HEATER



HAY TUBE



Note:

Make intake opening large enough so that heater can fit snugly and rigidly over the exhaust pipe. Solder all joints.

Scale: 3/16" = 1"

4. Procedure
   a. Weigh split sleeve - Record weight
   b. Fill sleeve with hay sample
   c. Weigh sleeve full of green sample - Record weight
   d. Place outside cylinder on car exhaust
      (1) Start motor to idling speed
      (2) Put split sleeve in cylinder
         (a) Screen covered end of split in first
         (b) Speed up car motor
      (3) Leave split sleeve in place 15 or 20 minutes
      (4) Remove split sleeve and reverse
         (a) Screen covered end outside
         (b) This prevents loss of leaves as sample dries
5. At end of 25 minutes of drying
   a. Remove split sleeve and get total weight of sleeve and sample - Record this weight
   b. Return split sleeve to cylinder
      (1) Screen end out
      (2) Leave for 5 minutes
   c. Weigh split sleeve and sample again
      (1) If weight has been lost return sleeve to cylinder for 5 more minutes
      (2) Remove sleeve and weigh again
      (3) Continue this procedure until total weight of sleeve and sample is constant
6. Check moisture loss and percent of moisture in sample
   a. Subtract weight of split sleeve only from original total weight of sleeve and green sample. This is weight of green sample.
   b. Subtract weight of split sleeve and dried sample from weight of split sleeve and dried sample. This is weight of moisture lost.
   c. Divide weight of moisture lost by weight of green sample. This is percent of moisture in green sample before drying.

B. Heat Lamp Moisture Tester
   1. Cut green sample of hay into short lengths (about 1/2 inch long)
   2. Place sample cuttings in drying cup
      a. Add or subtract enough cuttings so scale balances
      b. Turn on heat lamp for 20 minutes
      c. Adjust balance on dryer
      d. Leave sample in tester 5 minutes more
      e. Adjust balance again
      f. Repeat until no more weight loss occurs
      g. Read scale - Reading shows moisture content of original green sample.

C. Electronic Moisture Testers

1. Too expensive for most field work
2. More suitable for laboratories
3. Developed primarily for grain testing
4. Can be used for testing hay moisture content but cost too high to justify use of equipment.

T. AUTOMATIC CONTROL EQUIPMENT FOR HAY AND GRAIN DRYING

I. Types of Control used in Crop Drying
  A. Motor overload protecture
  B. Off-peak operation control
  C. Air temperature control
  D. Air humidity control
  E. Hay temperature control
  F. Combination of above controls

II. Motor overload protecture
  A. Internal Thermostat
    (1) Manual reset safest
    (2) Automatic reset can be used
      (a) Not safe for operator
      (b) Open motor control switch when making mechanical or electrical adjustments
  B. Motor Overload Control
    (1) Use magnetic type
    (2) With heater to operate switch release mechanism
    (3) Use manual reset type
    (4) Remote Control of Motor Starter
      (a) Permits control of fan motor without going to fan room
      (b) Saves time.

III. Off-Peak Drier Operation Control
  A. Overcomes objection of manager and board to large power uses
  B. Prevents farm production uses from adding to peak power consumption demand on line.
  C. Reduces Drier Operating Costs
    (1) Reduces danger of motor burn outs due to low voltage
    (2) Reduces manual attention to starting and stopping drier fan
  D. Night Operation Drier
    (1) Speeds drying during first three days
    (2) Beneficial to cooperative
      (a) Increases consumption of power in off-peak hours
      (b) Prevents unnecessary addition to peak demand on system
    (3) Night operation not recommended in last half of drying period.
      (a) May extend drying time
      (b) Off-peak day time hours sufficient for proper drying.
  E. Teaches member how to make best use of power for benefit of both himself and the cooperative

IV. Air Temperature Controls for Fan Motor
  A. Thermostatic Type
    (1) Regular Relay Control of Motor starter
      (a) With standard thermostat
        (1) High voltage type
        (2) Low voltage type
        (3) Starts motor when temperature rises to the setting
        (4) Stops motor when temperature falls below setting
      (b) Reverse thermostat
        (1) High voltage type
        (2) Low voltage type
        (3) Starts motor when air temperature drops to setting
        (4) Stops motor when air temperature rises above setting
  B. Humidistat Type
    (1) Sensitive to moisture content of air
      (a) Operated by tension of hair which opens and closes circuit
        (1) High voltage type
        (2) Low voltage type
      (b) Electronic control
        (1) Sensitive plastic cylinder changes conductivity with moisture condition of air
          (a) Small quantity of electricity amplified by electronic tube operates relay controling motor starter
          (b) Low voltage type
        (2) Stops motor at 45 degree F.
        (3) After stopping motor due to low temperature humidistat must be reset by hand
        (4) Controls humidities from 50% to 100%

V. Hay Temperature Control
  A. Thermostat located in hay
    (1) Near center of hay mass
    (2) Starts blower fan if hay heats
  B. Low Voltage Type
    (1) Operates relay in motor starter assembly
    (2) Need wide differential thermostat
      (a) 30 degrees to 50 degrees F.
      (b) Keeps fan running after heat is removed from hay
      (c) Stops fan at low temperature
    (3) Some types keep fan running and must be cut off by hand

B. Grain Temperature Control
   (1) May be same as hay temperature controls
   (2) May be used to freeze grain
      (a) In late fall
      (b) To hold damp grain until spring for drying without heat

VI. Combination of Controls
   (a) Motor may be protected
      (1) From internal heat
      (2) From over current
      (3) From low voltage
   (b) Crop may be protected by a combination of controls
      (1) Controls sensitive to air temperature
      (2) Controls sensitive to moisture
   (c) Off-Peak Controls
      (1) May be used with any one or all of the above controls
      (2) May stop drying
         (a) For the highest daily peak
         (b) For all daily peaks

U. MECHANICAL HAY GATHERING EQUIPMENT

I. Mowing Machines
  A. Horse-Drawn Mowers
  B. Tractor Mowers
    (1) Mounted on side of tractor
      (a) Permit pulling hay rake as mowing is done
      (b) May be necessary in hot climates
        (1) To prevent leaf shattering
        (2) To prevent fading and overdrying
    (2) Trailer-Type Mower
      (a) Mounted on drawbar of tractor
      (b) Mounted on wheels pulled by tongue hitch
      (c) Prevent use of rake with mower

II. Hay Rakes
  A. Horse Drawn
    (1) Dump rakes
    (2) Side delivery rakes
  B. Tractor rakes
    (1) Dump rake
      (a) Not built for tractor use
      (b) Horse drawn dump rake may be ádopted to tractor power
    (2) Side Delivery Rake
      (a) Triple Beaters on a reel-driven by rake wheels
      (b) Four beater on a reel
        (1) More gentle action than a three beaters
        (2) Moves hay shorter distance
      (c) Power type Side Delivery rake
        (1) Either 3 or 4 beaters on reel
        (2) Belt driven from power take-off on tractor
      (d) Morrill side-delivery rake
        (1) Five large diameter wheels
        (2) Each wheel floats free
        (3) For use in rough land
        (4) Gentle action - Moves hay short distance

III. Hay Loaders
  A. Trailer type
    (1) Pulled behind hay rack
    (2) For loose long hay only
  B. Wagon Unloaded
    (1) By Harpoon
    (2) By slings
    (3) By hand

IV. Field Choppers
  A. Have pick-up attachment - Lifts hat into machine
  B. Hay chopped
    (1) Into 3 or 4 inch lengths
    (2) Blown into trail wagon
  C. Unload from wagon
    (1) By hand
    (2) By power unloader

D. Chopped Hay Blowers
   (1) Blow hay into barn
   (2) Pipe distributors locates hay on dryer

V. Pick-Up Hay Balers
   A. Have pick-up attachment that lifts hay from swath or window into machine
   B. Field Bale Loaders
      (1) Directly on to trail wagon
      (2) To sled pulled behind baler
         (a) Dump-type sled
            (1) Heaves bales in small piles
            (2) Later picked up
               (a) By hand
               (b) With bale loader
         (b) To flat slip
            (1) Holds 20 to 30 bales
            (2) Each slip load pulled to hay storage location

VI. Field Bale Loaders
   A. Mounted on tractor
      (1) Pick up bale from ground
      (2) Delivers bale to trail wagon
   B. Mounted on truck
      (1) Located on side of truck
      (2) Delivers bale to truck bed

VII. Buck Rakes
   A. Pick up hay from windows
   B. Hay delivered to barn or stack
   C. High speed delivery
      (1) Small loads 350 to 700 pounds
      (2) Tractor runs in high

VIII. Buck Rake Stackers
   A. Mounted on tractors or trucks
   B. Pick up loose or baled hay in field
   C. Transport hay to stack or barn
   D. Elevate hay to top of stack
   E. When carried to barn
      (1) U se inclined elevator for bales to put hay in mow
      (2) Use hay carrier and truck
      (3) Use harpoon for elevating loose hay in barn

V. Air Heating equipment for Hay Driers

I Types of Air Heaters

A. Direct Heaters
   (1) All burned gases go into drier
   (2) Danger of fire from sparks
   (3) Very economical on fuel cost

B. Indirect Air Heaters
   (1) Sometimes called heat exchangers
   (2) Use 40 to 50 percent more fuel
   (3) Burned gases diverted from drier
   (4) Less danger of fire.

II Oil Burner Heaters

A. Single Oil Burners

B. Double Oil Burners

C. Use High Pressure Guns

D. Type of Air Heating
   (1) Direct Method - lowest fuel cost
   (2) Indirect method - highest fuel cost

E. Fan Driven by Motor
   (1) Propeller type fans
      (a) Tube axial
      (b) Vane axial
   (2) Capacity of fans
      (a) Generally smaller diameter than non-heated blower units
      (b) Blow 2/3 to 3/4 the volume of air
      (c) Produce higher pressures
         (1) To 5 inches of water
      (d) Portable Units
         (1) Can be used without heat
         (2) Taken from bin to bin
         (3) Short drying time enables operator to use equipment on several bins..

III Not recommended unless

A. Climatic conditions are unfavorable
   (1) Late fall in cold weather
   (2) Heavy rainy season or high humidity

B. Cost of fuel major investment in drying with heated air
   (1) Cost ranges from 1 to 10 cents per bushel for fuel
   (2) Requires attendant to supervise equipment

IV Excessive heat damages grain

A. For seed, air temperature limited to 110° F.

B. For feed, air temperature limited to 104° F.

C. For wet or dry milling, air temperature limited to 104° F.
   (1) Higher temperatures may damage wheat gluten
   (2) In corn, high temperature injurious to starch

W. DRIER OPERATION PROCEDURE

I. Place Hay Uniformly on Drier
   A. Long Hay
      1. See that tropey hay is torn apart
      2. Tramp hay uniformly
         (a) This prevents the formation of air passages
         (b) Too much tramping in spots prevents air penetration
      3. See that hay forms air seal beyond ends of main and lateral ducts and slatted floor
         (a) Have at least 2 feet more hay beyond main duct opposite fans than on the sides
         (b) This stops air leaks from velocity pressure
      4. Do not walk on hay unnecessarily
         (a) Do not make paths
         (b) Keep visitors off the hay
      5. Tramp hay lightly around posts and along walks
   B. Chopped Hay
      1. Use an elevator blower to put chopped hay in place
      2. Keep off the hay if possible
      3. If trampling is done
         (a) Tramp surface uniformly
         (b) Tramp hay tightly around posts and slong walks
            (1) This prevents air leaks
            (2) Maintains air pressure
   C. Baled Hay
      1. Do not place more than 8 feet of baled hay on each side of main duct
      2. Use 10 feet of baled hay to seal main duct
         (a) To hold velocity pressure
         (b) To maintain air pressure
         (c) To get uniform air penetration

II. Start Blower Fan As Soon As Possible
   A. Green Hay heats quickly
      1. Start blower fan as soon as hay will develop some back pressure
      2. This will remove heat
      3. It also makes hay mow or stack the coolest place on the farm. It will keep workers cool.
   B. Check Air Escape as hay is placed
      1. High velocity air indicates an air leak
      2. Place hay to stop leaks
      3. After first hour hot air at edges of drier indicates poor air penetration of air.
         (a) May be caused by air pressure leak
            (1) Check sides and ends of drier
               (a) At floor line
               (b) Over entire surface
            (2) Check on top of hay
               (a) Over main duct
               (b) Around posts and walks
         (b) Stop Air Leaks
            (1) On Top of Drier
               (a) By trampling more hay in leak area
               (b) By putting more hay over entire top of drier

(2) On sides and ends
(a) Stop fan and go in main duct
(1) Partially cover openings to lateral ducts serving area where leak occurs
(2) Where no laterals are used cover interior surface of main duct
(a) Over area where outside leak occurs or along air inlet of slatted floors.
(b) Use canvas or heavy building paper
(c) After covering inside areas of main duct or limiting air flow in laterals
(1) Start fan again
(2) Check air leaks around drier
(3) If leaks still occur stop fan and make additional air flow adjustments

III. Check Air Temperatures
A. With thermometers
(1) Hang a thermometer in air inlet to fan room
(2) Place thermometer in hay around stack
B. Temperature Differences
(1) Escaping air should be cooler than ingoing air
(a) This indicates drying is taking place
(b) Lower temperature due to evaporation of water by the air
(2) If escaping air is warmer than ingoing air
(a) Indicates air volume not enough for drier
(b) May indicate a hot spot
(1) Try other locations around dryer
(a) If other places are cooler indicates air not penetrating properly at warm spot.
(b) Drive 2 x 4 into hay
(1) $\frac{1}{2}$ to 2/3 of distance to main duct
(2) Remove 2 X 4
(a) If air flow increases check temperature of escaping air
(b) If air still too warm drive 2 X 4 into hay near first opening as many times as necessary to get air flow started
(c) Use your hands to feel air temperature
(1) Thrust your hand and arm into hay as far as possible
(a) If the hay and air feel cool drying is progressing
(b) If the hay and air are warm or hot
(1) Air is not penetrating properly
(2) Speed up fan
(1) By changing pulley ratio
(2) Be sure to check load on motor
(a) Before changing pulley ratio
(b) After changing pulley ratio
(3) Do not overload motor by speeding up fan

IV. Blower Fan Operation
A. Run fan continuously
(1) First 3 to 5 days
(2) Except during system peak demand hours

B. When to stop fan
   (1) From sundown to sunrise after first 3 to 5 days
   (2) When air temperature is too low
      (a) Below 50oF for hay
      (b) Below 50°F for grain
   (3) When air humidity is too high
      (a) Above 60 per cent for hay
      (b) Above 80 percent for grain
      (c) During rain or heavy fog

V. How to tell when drying has been completed
   A. When ingoing and escaping air have the same temperature
   B. Check hay or grain in top of drier
      (1) If the top 18 inches of hay is dry stop blower fan
      (2) If the top 18 inches of grain is dry stop blower fan
      (3) Leave fan off for 24 to 48 hours
         (a) Then start fan
         (b) Check escaping air immediately
            (1) If air is warm or hot run fan 2 or 3 days more
            (2) Again stop fan for 48 hours time, then check
               (a) Start fan again
               (b) Check temperature of escaping air

I. Measure Barn to obtain dimension
   A. Drier - (Length and Width)
   B. Length of Main Duct
   C. Length of Lateral Ducts
   D. Size of Fan Room
      (1) Length, Width and Heighth
      (2) Location of Fan Room
         (a) Inside Barn
         (b) Outside Barn

II. Draw Up Floor Plan of Drier
   A. Show Fan Room
      (1) Length and Width
      (2) Location of Fan and Motor
      (3) Location of Air Inlet Area
      (4) Materials for Fan Room
         (a) Use 2 X 4 studding spaced 2 feet
         (b) Use 2 X 6 ceiling joists
            (1) Spaced 2 feet apart
            (2) Place directly over studs
            (3) Place 2 X 6 on edge for strength
         (c) Cever Walls and Top of Fan Room
            (1) With T and G Lumber
            (2) With Plywood
            (3) With Building Board
         (d) Place Door to Fan Room
            (1) Where hay will not obstruct entrance to fan room
            (2) Convenient to barn or loft entrances
      (5) List necessary materials including hardware
   B. Show Main Duct
      (1) Length, Width and Taper
      (2) Location of Lateral Ducts
      (3) Size of Lateral Duct Openings
      (4) Materials for Main Duct
         (a) Use 2 X 4 for framing
         (b) Cever with T and G lumber
         (c) Use 6 or 8 inch boards over air escape cracks on top of main duct
      (5) List necessary materials
      (6) List necessary hardware supplies
   C. Show Lateral Ducts on Slatted Floor
      (1) Show length, width and height
         (a) of lateral ducts
         (b) Show size of panels in slatted floor
      (2) Show location of laterals
         (a) In relation to sides of drier
         (b) In relation to posts or floor openings
      (3) Show air escape openings
         (a) Mark with red lines
         (b) Check for air seal
            (1) Along sides of drier
            (2) Around posts and openings

III. Show Information Needed for Making Air Escape Openings
  A. Size by Length and Width
  B. Location in Building
  C. Modification of existing openings

IV. Summarize materials needed
  A. To make barn floor air tight
    (1) Repair work necessary
    (2) Building paper or other materials
  B. Lumber Needed
    (1) By kind, size and length
    (2) Cost of Lumber
  C. Hardware Needed and Cost
  D. Labor needed
    (1) Skilled or unskilled
    (2) Farm Labor
      (a) To get building ready
        (1) To clean and trade
        (2) To repair floor, etc
  E. Include Fan and Motor
    (1) Size, Type and Phase of Motor
    (2) Motor starter and other controls
    (3) Building and Farmstead Wiring